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Verbal and Spatial Immediate Memory in Patients with Localized Cerebral Lesions

by

Catherine Deirdre Foster

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled Verbal and Spatial Immediate Memory in Patients with Localized Cerebral Lesions submitted by Catherine Deirdre Foster in partial fulfilment of the requirements for the degree of Master of Arts.

Date. August 13, 1984.

Dedication

To my son, Trevor James,
whose love and understanding over the past six years
encouraged me to follow my dreams.
Thanks Trev.

Abstract

Tests of both simple and complex verbal and spatial immediate memory (attention) span were administered to patients with neurodiagnostically confirmed focal lesions. Localization was obtained independent of neuropsychological examination. Performance of these patient groups was compared to matched normal controls. The tests employed were Digit Span Forward and Backward from the Wechsler Adult Intelligence Scale-Revised, and a modified form of the Knox Cube Test. This modification involved restructuring of the test to a form more analagous to digit span (series 2 to 7) as well as the addition of a 10 second delay trial. The immediate recall of the Knox Cube Test and the Digit Span Forward were classed as measures of simple spatial and verbal memory (attention); whereas, the Knox Delayed Trial and Digit Span Backward were regarded as more cognitively difficult tasks.

No differences were found on the measures of simple verbal or spatial immediate memory. It was found that patients with left anterior lesions were impaired on Digit Span Backward in comparison to both right anterior and right posterior lesion groups. In contrast, on the Knox Cube Delayed Trial patients with right posterior lesions were significantly worse than controls, left posterior, and right anterior groups.

These results were viewed as representing a double dissociation in terms of the effects of localized lesions on

immediate memory or attentional processes, and implicated material specific deficits related to localized cerebral lesions. The results were discussed in relation to previous studies, and directions for future research were suggested.

Acknowledgments

I would like to thank the members of my committee for assisting me in the preparation of this paper: Dr. Beck for his constant support and direction over the past two years; Dr. Dobbs for agreeing to join the committee so late in the process and adding a 'new dimension' to the study; and a special thanks to my mentor, Dr. Bornstein, who sent me 'into the woods with a survival kit and encouraged me to find my own way out.' In addition, I would like to thank my peers who offered their assistance in ways too numerous to mention; Sonja, Grant, Howe, Doug, Mary Sue, Rick, Cory, Karen and Larry. Further, I thank my brothers and sisters, particularly Ashley, Monica, Mary, and Freda, and my very special friend Eleanor, who have offered their continuous love and support with the assistance of B.C. Tel and A.G.T. Finally, I would like to thank the Natural Sciences and Engineering Research Council of Canada for their financial support during the preparation of this thesis.

Although the findings of this study do not shake the foundations of clinical neuropsychology, they have served the purpose of introducing me to the realities of human brain research without totally disillusioning me about the problems inherent therein.

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I. INTRODUCTION

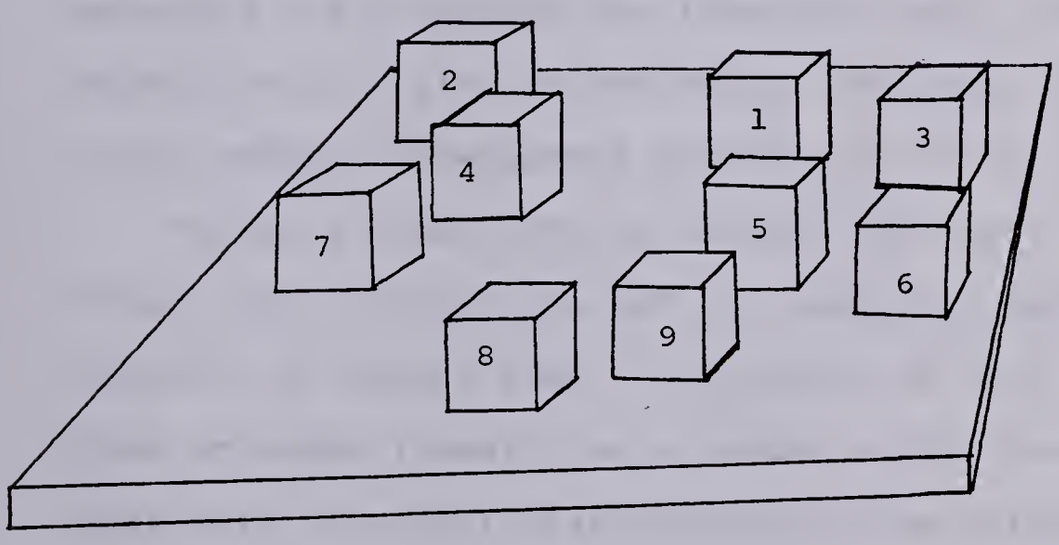
One of the principal goals of a clinical neuropsychological examination is to determine which cognitive functions have been affected and which have been spared. Typically, a comprehensive battery of neuropsychological tests is administered which allows for documentation of material specific (e.g. verbal versus nonverbal) and/or modality specific (e.g. auditory versus visual) deficits.

Assessment of immediate memory (attention span) is an integral component of neuropsychological assessment and a number of tests are available for this purpose. The Digit Span subtest from the Wechsler Adult Intelligence Scale-Revised (WAIS-R) is one of many well accepted and commonly used tests of auditory or verbal attention span (Wechsler, 1972). In addition, there are several different types of tasks used to measure visual or non-verbal attention. Among these are a number of different block tapping tests such as Corsi's Blocks (Milner, 1971), Arthur's revision of the Knox Cube Test (Arthur, 1947), and Kimura's revision of the Knox Cube Test (Kimura & McGlone, 1983).

The Corsi Block Test has been used by several researchers (De Renzi, Faglioni, and Previdi, 1977) to assess immediate and delayed spatial memory. It consists of nine cubes irregularly arranged on a board (See Figure 1). The task requires the patient to tap the cubes in the same

Figure 1. Corsi's block tapping board

(Milner, 1971).



order that they have been tapped by the examiner. Sequences from two to eight cubes (two series at each length) are tapped and the test is discontinued when both trials of a given length are failed. One point is scored if the first trial is correct and .5 is given if the second trial is correctly reproduced.

The block test used by Kimura is somewhat different from Corsi's in that there are five blocks arranged linearly on a wooden strip. The blocks are placed on the table on a diagonal to the patient (See Figure 2). Ten same length sequences are presented for immediate recall and then repeated with a five second delay. The score for each trial is the number of sequences correct out of ten.

The Knox Cube Test, as revised by Arthur (1947) in the "Point Scale of Performance", is used as a measure of attention or memory span. It consists of four 1 inch wooden cubes arranged linearly on a wooden strip (See Figure 3). There were no verbal instructions in the original version of the test, the examiner would first attract the patient's attention and then begin to tap the first series.

In Arthur's revision of the test, the number of taps in the series increased from two to seven and the test was discontinued when three series in succession were failed (Figure 4 shows the original order of taps in the series). Note that the successive increases in the span length are not uniform. A second trial was administered approximately one hour later in exactly the same manner as the first. The

Figure 2. Kimura's block tapping board (Kimura & McGlone, 1983).

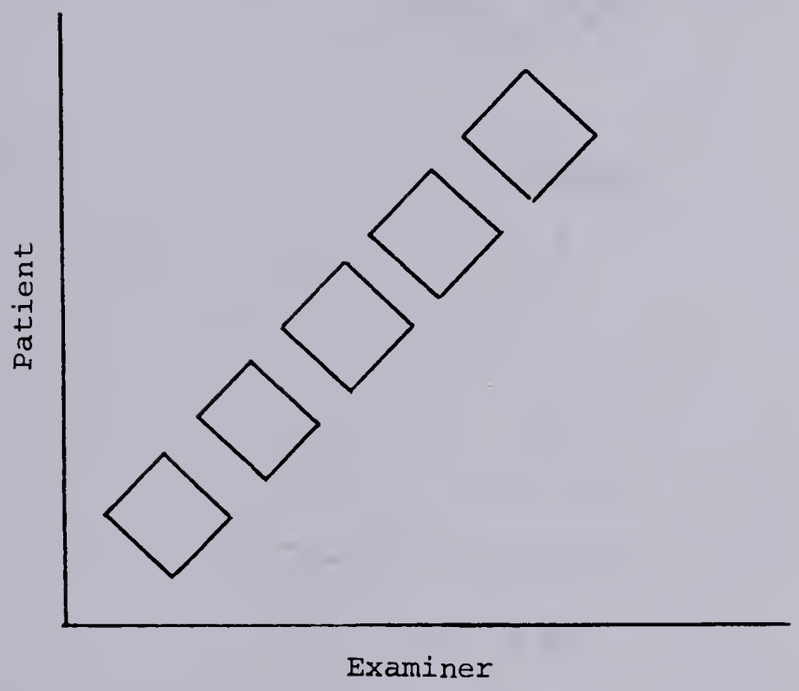


Figure 3. Arrangement of cubes in Knox Cube Test (Arthur, 1947).

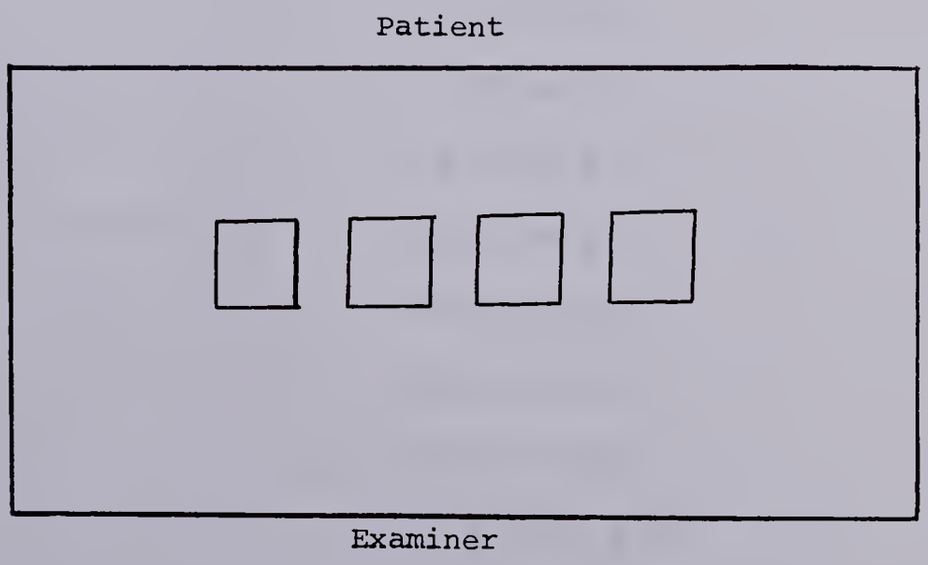


Figure 4.

Order of administration of trials on Knox Cube Test (Arthur, 1947).

Trial	Pattern
1	1 4
2	2 3
3	1 2 4
4	1 3 4
5	2 1 4
6	3 4 1
7	1 4 3 2
8	1 4 2 3
9	1 3 2 4
10	2 4 3 1
11	1 3 1 2 4
12	1 3 2 4 3
13	1 4 3 2 4
14	1 4 2 3 4 1
15	1 3 2 4 1 3
16	1 4 2 3 1 4
17	1 4 3 1 2 4
18	4 1 3 4 2 1 4

score for each trial was the number of series out of 18 repeated correctly and the score for the overall test was the average of the two trials. The raw score was then converted to a mental age for the person.

Adequate test-retest reliability for the Knox was demonstrated by Sterne (1966) and normative data was reported by Beardsley, Mathews, Cleeland and Harley (1978).

Recently, the construct validity of the test was demonstrated in a sample of 300 patients referred for neuropsychological examination (Bornstein, 1983). The patients were divided into two samples and given the Halstead-Reitan Battery, the Trail Making Test, the Wechsler Adult Intelligence Scale, the Wechsler Memory Scale, the Verbal Concept Attainment Test, and the Wisconsin Card Sorting Test in addition to the Knox Cube Test (Arthur's revision). The data were then subjected to a principal factors factor analysis.

It was found that the Knox loaded most heavily on a factor which also obtained high loadings on Digit Span Forward and Backward, the Seashore Rythm Test and the Speech Sounds Perception Test. This factor was interpreted as reflecting auditory and visual attention span. A somewhat weaker loading was obtained on a factor which was interpreted as a general non-verbal visuospatial factor. In both samples, the highest correlations with Knox were found with Digit Span Backward and Trail Making Test. In addition to attention, these tasks also have a strong sequencing

component .

On the basis of these findings, it was concluded that the pattern of inter-relationships suggests that the Knox Cube Test is primarily a measure of immediate visual-spatial attention and secondarily, appears to have a strong sequencing and visuospatial memory component.

De Renzi and Nichelli (1975) examined verbal and non-verbal short term memory impairment following hemispheric damage in 125 patients grouped according to lesion site and 30 controls. Four tasks were used; digit span forward, digit pointing span, picture pointing span, and spatial pointing span (Corsi Blocks). They found that on the digit span task and both of the other verbal tests not requiring speech (digit pointing and picture pointing span) patients with left hemisphere damage were impaired in comparison to normals, while the right hemisphere damaged patients were not. However, spatial span was affected by a lesion in the posterior portion of either hemisphere.

De Renzi, Faglioni, and Previdi (1977) compared patients with unilateral lesions with and without visual field defects to control patients. They used the Corsi Blocks to assess: 1) the span of immediate reproduction; 2) the recall of a subspan string after a filled or unfilled delay; and 3) the learning to criterion of a supraspan string. They found that the pattern of deficits varied with the type of task employed. That is, immediate spatial span was found to be affected by injury producing visual field

defects regardless of the side of the lesion. Delayed reproduction of a three tap sequence was performed more poorly by patients with right hemisphere damage and visual field defect than by controls. This was true whether the delay was filled or unfilled with a distractor task. Learning a supraspan sequence to criterion, up to a maximum of 50 trials, was failed by 65% of the right hemisphere damage with visual field defect group. This percentage was significantly higher than controls and any other brain damaged group. These findings point to the role of the posterior regions of either hemisphere for subserving immediate spatial memory as well as the dominant role of the right hemisphere when delayed recall was introduced.

From the previously cited literature it appears that, in general, measures of visual or spatial attention can be useful tools in neuropsychological examination. However, it is difficult to compare and contrast tests of auditory attention span such as digit span with tests of visual attention span when the structure and scoring of the tests are so diverse. For example, in Arthur's version of the KCT the number of series of each length is not uniform and the score is the number correct rather than the length of the longest span successfully repeated. Corsi's test, on the other hand, uses two series of each length but does not incorporate a delay component. In contrast, Kimura's test employs a five second delay but does not address the problem of span length as all ten series are the same length.

Bornstein (1983) suggested several modifications to the KCT which employ the basic stimuli of the original test and incorporate many of the features of block tests in the literature that have been useful in the documentation of attentional deficits.

The first modification involved reorganizing the test with pairs of series increasing in length making it more analagous to digit span tasks. Next, item difficulty data was used to equate the series within each pair for difficulty (Wright & Stone, 1979). And finally, a ten second unfilled delay was introduced in which the examiner covered the cubes with a blank sheet of paper. Administration of this revised version of the KCT was continued until two trials of a given length were failed and the score was the highest span successfully repeated. These modifications were implemented in the development of a revised KCT (KCT-R) and normative data have been collected (Bornstein, unpublished data). From this point onward this revision will be referred to as KCT-R and the immediate and delay trials will be referred to as KCT-I and KCT-D respectively.

The main focus of the current research is to explore the usefulness of KCT-R in assessing spatial (in contrast to verbal) attention or immediate memory span deficits in patients with localized cerebral lesions. More specifically, the following questions are addressed:

1) Is there a difference in performance between patients with right and left hemisphere lesions on KCT-I.

2) Furthermore, within each hemisphere is there a difference in performance on the KCT-I between patients with anterior vs posterior lesions.

3) In addition, does the introduction of a delayed recall trial increase sensitivity of the test to the effects of localized lesions.

4) As a corollary to the above hypotheses it was of interest to determine whether evidence of material or modality specific deficits could be derived. As the span length of KCT-R is parallel to that of digit span tasks it was possible to compare performance across modalities.

II. METHOD

A. Subjects

Five groups of subjects were used in the study; four experimental groups and one control group. The experimental subjects were patients referred for neuropsychological examination at The University of Alberta Hospital. They were divided into four groups according to hemispheric locus of the lesion; Right Anterior (RA) damage, 19 subjects; Right Posterior (RP) damage, 9 subjects; Left Anterior (LA) damage, 17 subjects; and Left Posterior (LP) damage, 7 subjects.

The site of the lesion was determined by radiological, neurological and surgical findings and was independent of neuropsychological examination. The criterion for assigning patients to anterior versus posterior groups was determined by extending an imaginary line downward from the central sulcus. Lesions in front of this line were placed in the anterior groups, whereas, lesions behind it were placed in the posterior groups. Thus, the anterior groups included patients with frontal, temporal, or fronto-temporal lesions, whereas, the posterior groups included patients with parietal or temporo-parietal damage. There was one patient included in the study who had a fronto-parietal astrocytoma who was placed in the RP group as the parietal damage was more extensive.

The subject diagnoses fall into one of five broad categories; head injury, epilepsy, cerebrovascular, tumor and other. The "other" group includes patients with intraventricular cysts, cerebral atrophy and temporal lobectomy. No data was available on lesion size. Table 1 shows the number of subjects from each brain damaged group in each etiological category.

The control group was obtained from a subsection of subjects recruited as part of a large scale normative study. Any subjects with a history of psychiatric or neurological illness were excluded from the study. Therefore, these subjects could be considered a "normal" control group. The controls were selected so that they matched the brain damaged subjects on age (within 2 years), education (within 1 year), and sex.

B. Materials and Procedure

Four tests were employed in the study: two auditory attention span tests, and two visual attention span tests. The auditory attention span tests used were the Digit Span Forward (DSF) and Digit Span Backward (DSB) subtests from the Wechsler Adult Intelligence Scale-Revised (WAIS-R).

For both Digit Span Forward and Digit Span Backward the standardized administration procedure was adhered to (Wechsler, 1981). For readers unfamiliar with these instructions, the examiner tells the subject that he/she is going to read some numbers and following that the subject

Table 1.

Number of Subjects from each Lesion Group in each Etiological Category.

	Lesion Groups				
Diagnosis	RA	RP	LA	LP	Total
Head Injury	1	0	3	2	6
Epilepsy	4	1	3	0	8
Cerebrovascular	1	3	3	2	9
Tumor	7	3	5	2	17
Other	6	2	3	1	12
Total	19	9	17	7	52

will be asked to repeat them. For Digit Span Forward the subject was asked to repeat the numbers in the same order and for Digit Span Backward the subject was asked to repeat the numbers in the reverse order. The digits were presented auditorally to the subject at the rate of one per second. Sequences increase in length from 3 to 9 digits for Digits Forward (2 to 7 digits for Digits Backward) and there were two series at each sequence length. See Figure 5 for a sample of the order of presentation for the digit span tasks. The tests were continued until two series of a given length were failed. The scoring procedure used for the current research was somewhat different from that used in the standard manual. That is, rather than a scaled score, the length of the longest sequence successfully repeated was used.

The visual memory span tests used in the study employed the modified form of the Knox Cube Test (KCT-R) as suggested by Bornstein (1983). The KCT-R consists of four 1 inch wooden cubes attached at equal intervals to a wooden strip (10.5 inches long and 1.5 inches wide). Both an immediate and a delay trial were used. For the immediate recall trial the instructions to the subject were: "I am going to touch these cubes in a certain order, watch me carefully then you touch them in the same order that I did". The examiner then taps the cubes at a rate of one per second. The subject must observe, memorize, and then tap the cubes in the same order. The difficulty and number of taps in the series increased

from two to seven (Figure 5 shows the order and number of taps in the series for both the immediate and delay trials of KCT-R). Two sequences, equated for difficulty, were given at each length and the test was discontinued after failure on both sequences of a given length. The subject's score was the longest span successfully repeated.

The same apparatus was used for both the immediate and delayed trials. The delayed trial instructions to the subject were: "I'm going to touch these cubes in a certain order like I did before. Watch me carefully then you touch them in the same order that I did. This time, wait to touch them until I tell you". After the examiner presented the sequence, the blocks were covered with a blank sheet of paper for a ten second unfilled interval. Following this the subject was asked to tap out the same sequence. The scoring procedure was the same as for the immediate condition.

All of the tests were administered on a one-to-one basis with the subject seated directly across the table from the examiner. The order of administration of the complete test battery was as follows: First, the Wechsler Memory Scale and the Aphasia Screening Exam were administered; then, either KCT-I or KCT-D was given; this was followed by the WAIS-R which contains DSF and DSB; and finally, either the KCT-I or KCT-D (whichever was not given earlier) was administered.

In the context of this study, both Digit Span Forward and KCT-I were viewed as measures of simple verbal and

Figure 5.

Sample order of presentation of digits for digit span tasks (left), and order of blocks tapped for Knox Cube Test-Revised (right).

Digit Span Test	Knox Cube Test-Revised
3 6	1 4
4 2	2 3
5 1 7	2 1 4
4 2 6	3 4 1
7 2 1 6	1 4 2 3
3 8 5 2	1 3 2 4
6 5 8 3 7	1 3 1 2 4
9 3 4 6 2	1 4 3 2 4
8 7 6 5 9 4	1 3 2 4 1 3
1 8 5 7 2 6	1 4 2 3 1 4
2 9 7 3 8 4 1	4 1 3 4 2 1 4
9 1 3 8 7 2 4	3 2 4 1 3 4 2

spatial attention span; whereas, Digit Span Backward and KCT-D were regarded as measures of more complex (or difficult) auditory and visual attention span respectively.

C. Analysis

Preliminary analyses were conducted to determine whether the groups differred on demographic data. These included analysis of variance on age and education in addition to chi square analyses on sex and etiology of lesion.

The data were analyzed in a 3 X 3 incomplete factorial design with side of damage (Right and Left) and position of lesion (Anterior and Posterior) as factors. There was one control group. A multivariate analysis of variance (manova) with KCT-I and KCT-D as dependent variables and age as a covariate was conducted using the SPSSX program "MANOVA". In addition, a manova was conducted using DSF and DSB as dependent variables with age as a covariate. Subsequent to a significant multivariate finding for any effect, univariate follow up analyses were carried out as suggested by Hummel and Sligo (1971). Multiple comparisons were conducted for any significant univariate finding using Tukey's-Honest Significant Difference (HSD) Procedure. Since the length of the spans for the digit and cube tests were similar, cross-modal t-test comparisons between DSF and KCT-I and DSB and KCT-D were conducted within each lesion group. Finally, t-test comparisons were carried out between DSF and DSB as

well as KCT-I and KCT-D to compare performance on simple versus complex tasks within each lesion group.

III. RESULTS

The first step in data analysis was to compare the groups on demographic variables. The age, sex and education for each group can be seen in Table 2. Analysis of variance showed a significant effect for age, $F(4,100) = 3.3$, $p < .05$. Tukey's multiple range procedure revealed that the RP group was significantly older than the LA and LP groups, $p < .05$. No significant differences were found among the groups on level of education, $F(4, 97) = .13$, NS. Chi square analyses showed that the groups do not differ in proportion of males to females, X^2 (3) = 7.66, NS, or in terms of etiology, X^2 (12) = 10.3, NS. It is clear that the groups do not differ on sex, education, or etiology of lesion. Because the right posterior group was somewhat older than the other lesion groups subsequent analyses incorporated age as a covariate.

The next step in analysis involved examining intergroup differences. The multivariate analysis of variance of KCT-I and KCT-D with age as a covariate revealed no significant main effects for side or position of lesion, however, there was a significant side-by-position interaction, Roy's $\theta=.093$, S=1, M=0, N=48; $F(2, 98) = 5.0$, $p < .05$ (Timm, 1975). Figure 6 shows the side-by-position interaction effects for KCT-I and KCT-D. Follow up univariate analysis of variance showed no significant effect for KCT-I, $F(1, 99) = 3.14$, NS; and a significant effect for KCT-D, $F(1, 99) = 10.06$, $p < .05$. Post hoc (Tukey's-HSD) analysis of means for

Table 2.

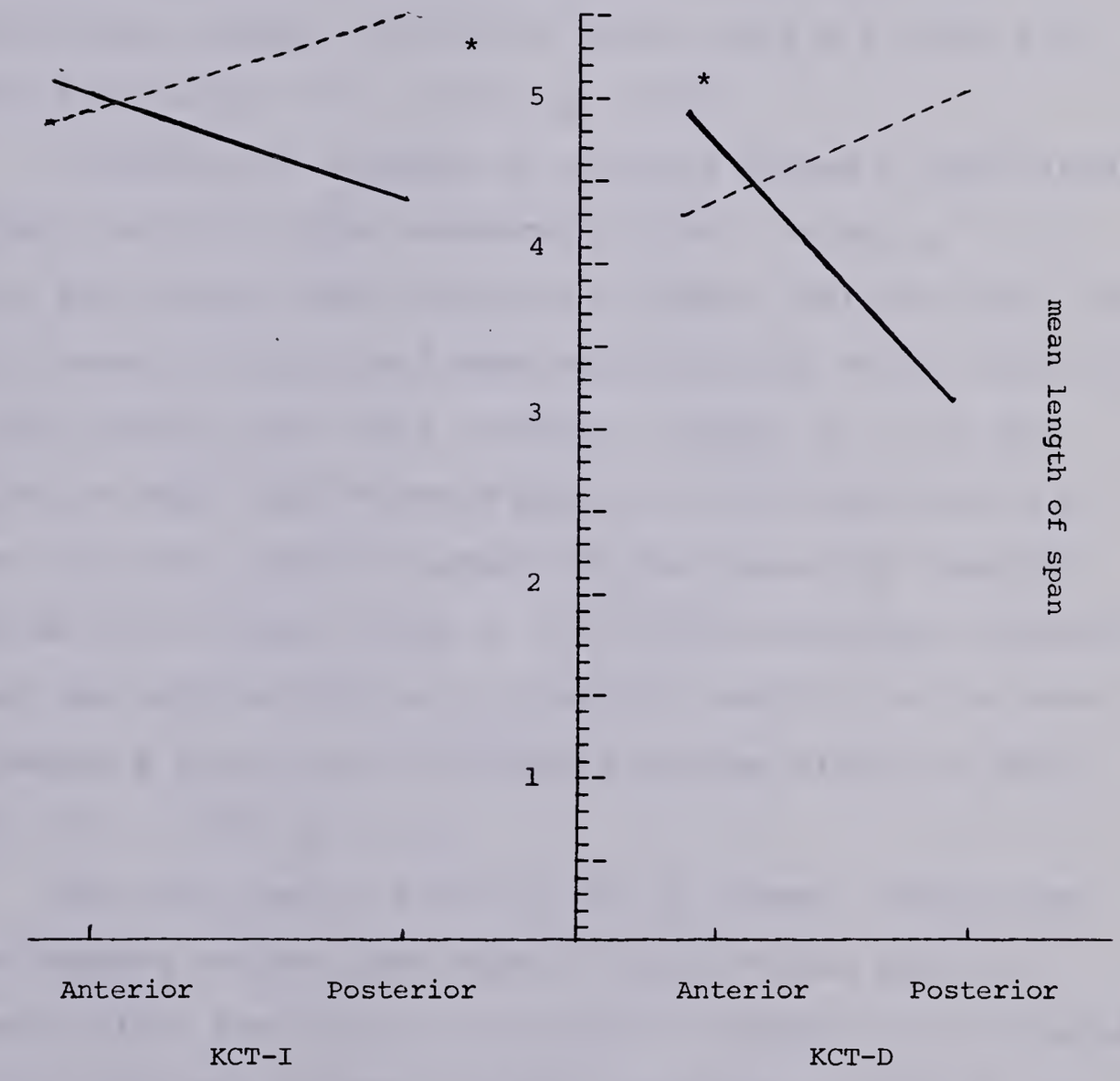
Demographic data for each Brain Damaged group and Controls

Lesion Group	Mean Age (in years)[a]	Mean Education (in years)[a]	Males	Females
Right Anterior	37.8 (13.05)	12.3 (3.66)	10	9
Right Posterior	47.5 (14.88)	11.7 (4.18)	8	1
Left Anterior	31.1 (10.65)	11.9 (4.20)	6	11
Left Posterior	28.4 (8.22)	11.4 (1.6)	5	2
Controls	35.8 (12.9)	12.0 (2.55)	30	23

[a]Standard deviations in parentheses.

Figure 6.

Side-by-position Interaction Effect
for KCT-I and KCT-D.



Right hemisphere ———

Left hemisphere ------

Controls *

KCT-D indicated that the right posterior group performed significantly worse than the right anterior, left posterior and control groups, $p < .05$, (See figure 7). The manova for DSF and DSB showed no significant main effects for position or side-by-position interaction, however, there was a significant effect for side of lesion, Roy's $\theta=.208$, $S=1$, $M=0$, $N=22.5$; $F(2, 47) = 6.19$, $p < .05$.

A univariate analysis of variance showed a significant effect for Digit Span Backward, $F(3,48) = 4.44$, $p < .05$. Post hoc (Tukey's-HSD) analysis of means indicated that the left anterior group performed significantly worse than the right anterior and right posterior groups, $p < .05$. The anova on Digit Span Forward did not reach significance at the .05 level. Table 3 summarizes the means and standard deviations for each group on each of the variables. However, when age was included as a covariate, analysis of variance revealed a significant difference between groups on DSF, $F(3, 47) = 3.04$, $p < .05$.

The next step in analysis was to compare intragroup performance on the cross modal (visual versus auditory) tests within each group. A series of t-tests for correlated means were done on DSF with KCT-I and DSB with KCT-D. As previously mentioned, DSF and KCT-I were considered measures of simple attention span, while DSB and KCT-D are regarded as measures of more difficult or complex attention span (immediate memory). No significant differences were found in the simple auditory versus visual attention span tasks for

Figure 7.

Venn Diagram depicting how the Lesion Groups Differ on KCT-D

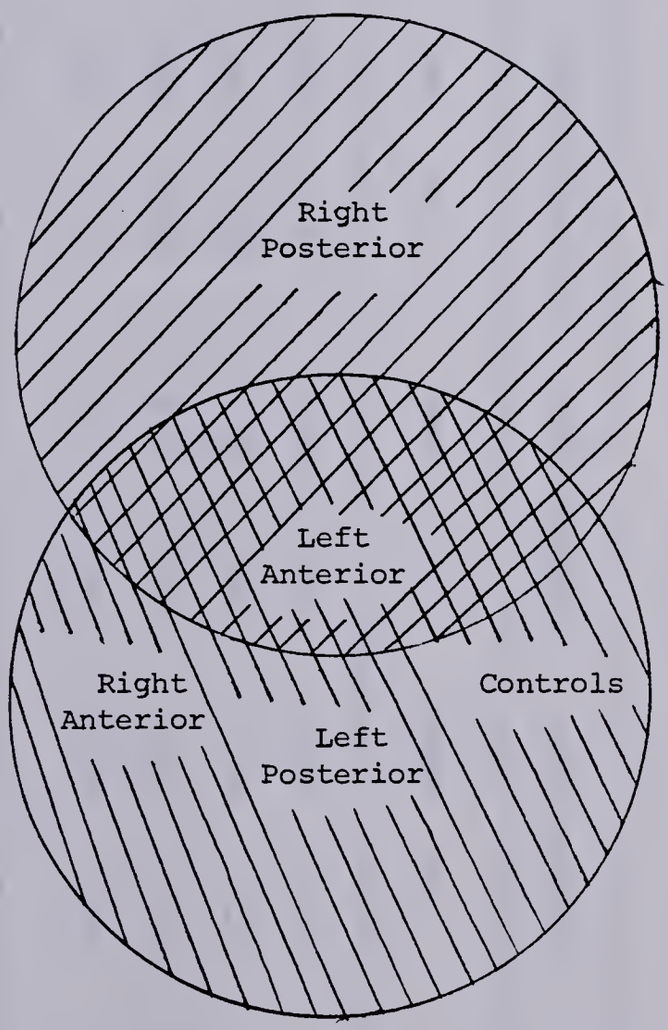


Table 3.

Means and Standard Deviations for each group on four Measures of Attention Span.

	Right Anterior		Right Posterior		Left Anterior		Left Posterior		Controls	
Test	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
KGT-I	5.21	1.13	4.55	1.01	4.88	0.99	5.43	0.97	5.28	1.03
KCT-D	4.90	1.19	3.22	1.39	4.35	1.06	5.00	1.15	5.03	1.02
DSF	5.68	1.00	5.67	1.32	4.41	1.87	5.14	1.77	-	-
DSB	4.00	1.05	4.22	0.97	2.77	1.48	3.29	0.95	-	-

the right anterior, left anterior or left posterior groups. However, the right posterior group showed a significant difference, $t(8) = 2.29$, $p < .05$, with performance on digits forward better than KCT-I. All of the t-tests for correlated means on the more difficult memory (attention) span tasks were significant. Table 4 shows the results of the t-test comparisons on simple and complex memory span tasks. From Table 4 it can be seen that performance on KCT-D was better than DSB for the right anterior and both of the left hemisphere groups. In contrast, the right posterior group performed better on DSB than KCT-D.

Finally, t-test comparisons were carried out between simple and complex measures of verbal and spatial memory span within each lesion group, (See table 5). It was found that DSF was performed significantly better than DSB by all lesion groups. In addition, KCT-I was performed significantly better than KCT-D by the RP and LA groups; whereas, there were no differences in the RA, LP, and control groups.

Table 4.

Summary of t-test comparisons for DSF vs. KCT-I

DSB vs. KCT-D within each Lesion Group.

	DSF/KCT-I		DSB/KCT-D	
Lesion Group	t	(df)	t	(df)
Right Anterior	1.18	(18)	-2.93*	(18)
Right Posterior	2.29*	(8)	2.45*	(8)
Left Anterior	-1.05	(16)	-4.77*	(16)
Left Posterior	-.55	(6)	-4.77*	(6)

*$p < .05$.

Table 5.

Summary table of t-test comparisons between tests of auditory and visual attention span

	DSF/DSB		KCT-I/KCT-D	
Lesion Group	t	df	t	df
Right Anterior	5.66*	(18)	1.46	(18)
Right Posterior	3.51*	(8)	3.58*	(8)
Left Anterior	5.18*	(16)	2.50*	(16)
Left Posterior	4.04*	(6)	1.16	(6)

*$p < .05$.

IV. DISCUSSION

This study examined performance on verbal and spatial, simple and complex immediate memory span tasks in patients with localized cerebral lesions. It was found that, although the groups did not differ on sex, education or etiology of lesion, the RP group was older than both the LA and LP groups. On examining the intergroup differences it was found that the groups did not differ on measures of simple immediate memory. However, there were differences on the more difficult tasks. Specifically, on KCT-D the RP group performed significantly worse than the RA, LP and control groups. On DSB the LA group performed worse than the RA and RP groups. These intergroup differences remained robust when age was included as a covariate and in addition, the anova between the lesion groups on DSF became significant. This was probably because of the fact that although the RP group is older, it performed better on DSF than any other lesion group. The next step in analysis was to examine the intragroup pattern of performance across modalities for both simple (DSF vs. KCT-I) and complex (DSB vs. KCT-D) memory span tasks. Only the RP group showed a significant difference for the simple memory span comparison with performance on DSF better than KCT-I. All of the comparisons for the more difficult tasks were significant. As expected KCT-D was better than DSB for both of the left hemisphere groups and DSB was better than KCT-D for the RP group. However, DSB was worse than KCT-D for the RA group. This

unexpected finding will be discussed later. Finally, it was of interest to look at the intragroup differences between simple versus complex verbal and spatial memory span tasks. Within each lesion group DSF was performed significantly better than DSB. In addition, KCT-I was performed better than KCT-D by the LA and RP groups. However, as expected from the previous analyses there were no differences between the immediate and delayed trials for the RA, LP and control groups.

To summarize the findings in terms of the explicit hypotheses: There were no differences between the lesion groups on measures of simple immediate memory (attention) span (KCT-I). For KCT-D, the deficit was not simply related to either side (right versus left) or position (anterior versus posterior) of the lesion, but rather a side-by-position interaction effect was obtained. Thus it was patients with RP and, to a lesser extent, LA lesions who showed the greatest deficit on a test of delayed spatial memory (KCT-D).

Prior to discussing the present findings a number of general issues will be considered. The possibility of a primary visual or motor deficit should first be ruled out. All of the patients in the study were able to visually locate and physically reach out and tap a minimum of two cubes. This suggests that they were not suffering from a gross primary visual or motor defect.

Another issue which should be considered is that of lesion size. It has been suggested in the literature that patients with right, as opposed to left, hemisphere lesions generally tend to have more extensive brain damage prior to seeking medical intervention (Milner, 1964). This argument presumes that left hemisphere lesions more often compromise language functions which are more readily apparent to the patient and others, thus resulting in the patient seeking medical attention relatively early in the course of their illness. Conversely, right hemisphere lesions may produce symptoms that are less immediately obvious, and which may result in greater periods of time between onset of illness and clinical presentation. Presumably, longer duration of illness would be related to further progression of the pathological process. There are however a number of interacting factors such as etiology and location of lesion which must also be considered in determining what brings a patient to medical attention. In regard to etiology, clearly, a sudden trauma or cerebrovascular accident affecting either hemisphere would require immediate medical intervention; whereas, a slow and insidious lesion on either side may not lead to distressing symptomology. In addition to etiology, lesion location may interact with lesion size in determining whether a patient seeks medical aid early in the disease process. It may be that small lesions in the motor strip in either hemisphere would lead to a noticeable deficit, whereas, a small lesion located elsewhere such as

the frontal association area may not lead to symptoms which would be readily noticeable to the patient. Bornstein & Witt (1984) examined patients with slow growing tumors (meningiomas) which had a left, right or bilateral locus and found no evidence of any differences between the groups with regard to size or age at presentation of lesion. This finding, at least in the case of meningiomas, refutes the suggestion that right hemisphere lesions tend to be larger than left hemisphere lesions. In addition, in a subset of patients with lesions in the frontal association areas no differences were found between the left and right lesion groups. Bornstein & Witt (1984) cite evidence from case histories which illustrates the point that the relation between lesion size or location and symptomology tends to be subject to a great deal of individual variation. Case no. 1 was a 42-year-old woman who complained of dizziness and a heavy feeling in her head for approximately 6-months. She was later diagnosed as having a small right-frontal lesion. Case no. 2 was a 66-year-old man with a 3-year history of transient dysphasia. He was admitted to hospital following an episode of loss of consciousness and right arm weakness and subsequently was found to have a massive left-frontal lesion. This illustrates that language deficits do not always bring left hemisphere patients to medical attention and, further, right hemisphere lesions are not invariably larger than left hemisphere lesions. In addition, patients with right hemisphere lesions are not necessarily older at

time of presentation.

On the one hand, the findings of Bornstein and Witt (1984) showed that there were no differences in lesion size between meningioma patients with left and right hemisphere lesions, on the other hand, the initial studies by Milner (1964) done on patients with temporal lobe epilepsy suggested that right hemisphere lesions tend to be larger than left. Patients in the present study had quite variable etiologies including both epilepsy and meningiomas. Further, in our study the group with the greatest deficit on visual attention span was also the oldest group. Taken together, these facts along with the small sample size might lead one to argue that differences in extent of lesion between right and left side cannot be excluded as a partial explanation of the results. Data on lesion size was not available for analysis in the present study, however, the findings do suggest that the immediate memory span of patients with RP lesions is specific rather than pervasive in that performance was poor on KCT-D and not on DSB. In point of fact, the RP group performed better on DSB than any other lesion group. Some other explanation must be found.

It may be that different mechanisms are responsible for the similar type of failure of RP and LA on KCT-D (DeRenzi, 1969). That is, the KCT-D may involve both a spatial and a language factor, the former affected by RH damage and the latter by LH damage. The language component may involve either verbal encoding of the stimulus or sequencing

ability. Nonetheless, these different components of the task may account for the discrepancy between our findings and those of DeRenzi et al. (1977). DeRenzi et al. (1977) used the Corsi Blocks to assess immediate and delayed spatial memory in patients with localized cerebral lesions and found that spatial span was affected by posterior lesions of either hemisphere. Further, the RP group performed significantly worse than controls when a delay was introduced. As mentioned earlier, the Corsi Block Test consists of nine cubes irregularly arranged on a board, whereas, the KCT-R consists of 4 cubes linearly arranged. It is possible that the arrangement of cubes in the KCT-R lends itself to easier verbal encoding (Kim, Royer, Bonstelle & Boller, 1980; Lezak, 1983) thus adding a verbal component to an essentially visuospatial task. This may be why, in our study, the LA group did not do substantially better than the RP group on KCT-D. It is possible that this LA group of patients were unable to use verbal coding strategies to assist them in remembering the sequence of cubes to be tapped. However, it does not account for the good performance on KCT-D by the LP group. Earlier research (De Renzi & Nichelli, 1975; De Renzi et al. 1977) indicates that visuospatial attention span is affected by lesions located posteriorly in either hemisphere. Because both of these studies employed the Corsi Blocks the discrepancy between their findings and the current research may simply be a reflection of the different type of cognitive processing

required by the two different cube tests.

Looking at the results from a somewhat different perspective it is possible to speculate about what may be happening in terms of brain behavior relationships within the frontal lobes. The intergroup comparison on KCT-D showed that the LA group was relatively impaired in that their performance did not differ significantly from that of the RP group. This relatively poor performance implies that they had some difficulty on KCT-D. As suggested earlier, (Kim et al., 1980; Lezak, 1983) this could be interpreted to suggest that KCT-D is amenable to verbal mediation. Thus, this LA group may be impaired in the application of verbal strategies to an essentially non-verbal test. In contrast, the intragroup, cross modal comparison showed that the RA group was impaired on DSB relative to KCT-D. Some researchers (Weinberg, Diller, Gerstman, and Schulman, 1972; Costa, 1975) have hypothesized a relationship between visuospatial deficit and poor performance on DSB. Weinberger et al. (1972) found that patients with RH lesions and visual field defects performed normally on DSF but were impaired on DSB. In addition, Costa (1972) found that patients with either right or left hemisphere lesions and visual field defects performed as well as normals and other brain lesion groups on DSF but worse than these groups on DSB. The implication here is that one strategy for repeating a set of auditorally presented digits in reverse order may be to first visualize the digits in the order they were presented

and then read them backwards (Costa, 1975). If this is true, our results could be interpreted to suggest that the RA group had some difficulty with DSB due to the impaired application of visuospatial strategies to an essentially verbal task. Thus one could conclude that patients with LA lesions do poorly on a visuospatial task which may be approached by using a verbal strategy; whereas, patients with RA lesions do poorly on a verbal task which may be approached by using a visuospatial strategy. Taken together, these findings imply that patients with frontal lesions may be impaired in the application of ipsilateral strategies to tasks which seem to preferentially engage processing in the contralateral hemisphere.

Another consideration which cannot be completely ruled out concerns the possibility of the patients having an apraxic disorder of the ideomotor type. According to Heilman (1979), ideomotor apraxia is a disorder of sequential, skilled movement which is not a result of weakness, tremors, akinesia, poor comprehension or intellectual deterioration. In light of this, one might argue that the poor performance in the RP group is not due to a deficit in immediate memory rather an inability to perform complex, sequential movements (KCT-D). Thus the patient can attend to the sequences but cannot reproduce them. It is difficult to completely rule out the possibility of apraxia in the current study, however, there is some evidence which makes it less likely as an explanation. That is, in right handed patients almost

all documented cases of ideomotor apraxia are from left hemisphere lesions (Geschwind, 1965; Hecaen & Sauguet, 1971). Left handed patients with right hemisphere lesions have been shown to exhibit an ideomotor apraxia (Heilman, Coyle, Gonyea, & Geschwind, 1973; Valenstein, & Heilman, 1978). However, because left handers tend to be more ambidextrous than right handers, apraxia is rarer in left handers (Hecaen & Sauguet, 1971). In addition, the motor sequences involved in KCT-I are exactly the same as those in KCT-D and, overall, the RP group performed significantly better on KCT-I. Furthermore, all patients in the study were capable of tapping at least two cubes in succession. It is thus unlikely that the patients with RP lesions were apraxic.

The present data are consistent with the prevailing literature on hemispheric specialization for processing different materials (verbal and nonverbal). Patients with RP lesions show a deficit on nonverbal (visual) memory; whereas, patients with LA lesions show a deficit on verbal (auditory) memory. The traditional verbal/nonverbal distinction however is now largely considered an inadequate dichotomy for understanding hemispheric specialization (Bradshaw & Nettleton, 1981; Bogen & Bogen, 1983). It is well beyond the scope of this paper to adequately cover the nature of hemispheric specialization, but for a comprehensive review see Bradshaw and Nettleton (1981). They examined a large body of literature on hemispheric

specialization of function and concluded that evidence from both normal and brain damaged subjects is most congruent with the analytic/holistic dichotomy as hypothesized by Nebes (1978). However, Bradshaw and Nettleton were more specific in suggesting that the left hemisphere is uniquely specialized for duration, temporal order and sequencing and hypothesize that right hemisphere specialization for simpler holistic or global processing occurs mainly by default. Bradshaw and Nettleton (1981) emphasize that they do not favor a true dichotomy and suggest that the difference in functioning between the hemispheres is 'one of degree rather than kind'. Thus one should approach hemispheric specialization not as a rigid dichotomy but rather as a continuum with each hemisphere having a relatively greater or lesser involvement in the processing of particular materials. There is mounting evidence which indicates that the right hemisphere is not strictly limited to nonverbal processing, for example, Zaidel (1978) using prolonged stimulation techniques has shown that although the right hemisphere is essentially mute it nonetheless has considerable comprehension abilities. Further evidence is provided by the takeover of some language functions by the right hemisphere subsequent to left hemisphere damage and aphasia (Zaidel, 1983). Similarly, it is clear that the left hemisphere is not limited to processing only verbally mediated material. Evidence from split brain studies indicates that the left hemisphere is capable of performing

visuospatial tasks including gestalt completion tests. (Zaidel, 1983). Attempts to sort out the specialization of the hemispheres for specific types of tasks is confounded by a number of issues. The degree of lateralization can vary considerably between individual subjects, in addition, there is the possibility of the lesioned hemisphere pathologically inhibiting the normal functioning of the undamaged side. Nonetheless, our data seem congruent with the analytic/holistic dichotomy in that DSB probably requires verbally mediated, sequential processing which would preferentially engage left hemisphere processing, while KCT-D more likely involves non-verbal, gestalt-like processing which would tend to engage right hemisphere mediation. Further, these data suggest that KCT-D seems to have some potential for engaging left hemisphere processing. This may involve either verbal encoding and/or a sequential component. Thus, relatively poorer performance is found on DSB with left hemisphere lesions and on KCT-D with RP and, to a lesser extent, with LA lesions.

It may be that regulation of attention is subcortically mediated and thus the laterality effects we found could be a function of material specificity of the tasks employed. This is the notion that attention may be regulated by the brain stem reticular activating system and that the hemisphere best suited to handle the task is preferentially activated depending on the demands of the task. Digit span which is essentially an auditory/verbal task tends to be relatively

better suited for processing by the LH. This is congruent with our finding that patients with LA lesions show a performance deficit over RA and RP lesion patients on DSB. Similarly, KCT-D which is considered a visuospatial/nonverbal task appears somewhat more amenable to RH processing. Hence, we find that patients with RP damage perform poorly on KCT-D. The concept of material specificity is consistent with the present data.

It should be noted that, in this study, the concepts of material and modality specificity cannot be unequivocally separated as the digit span tests were both auditory and verbal, whereas, the block tapping tests were both visual and nonverbal. It is of course possible to design verbal tests which are not auditory in nature as well as nonverbal tests which are not visual. The findings of De Renzi and Nichelli (1975) may shed some light on this issue. They used verbal tests which did not require speech (digit pointing and picture pointing) in addition to the digit span and spatial span (Corsi Blocks) tests. As mentioned in the introduction, they examined verbal and nonverbal short term memory impairment following hemispheric damage in patients grouped according to lesion site and controls. They found that on the digit span task, and both of the other verbal tests not requiring speech, patients with left hemisphere damage were impaired in comparison to normals, while the right hemisphere damaged group were not. Spatial span (Corsi Blocks) was affected by posterior lesions of either

hemisphere. Thus it appears that it was the verbal nature of the material and not the auditory modality which accounts for the left hemishere deficit. In light of this evidence, the best explanation for understanding the findings of the current research would be in terms of material specific deficits.

In conclusion, these data provide evidence of material specific deficits on more difficult immediate memory tasks, with little effect on more simple tasks. The intermodality pattern of memory deficits was such that patients with left hemisphere lesions showed relative deficits on auditory/verbal immediate memory while those with RP lesions showed relative impairment of visuospatial immediate memory. Further, the results for the intragroup comparison of the complex verbal and visual tasks provides evidence for the support of a double dissociation (Teuber, 1955) of function. That is, an RP lesion produces a relative deficit on KCT-D but not on DSB, whereas, an LA lesion produces a relative deficit on DSB but not on KCT-D.

In light of these findings, suggestions for future research are in order. In general, research on humans who have sustained natural or accidental lesions is inevitably somewhat imprecise. Natural lesions rarely, if ever, follow the neat anatomical boundaries delineated by man. However, the lesion groups could be made more distinct by excluding all subjects whose brain damage extends across the conventionally established boundaries (ie. temporo-parietal

or fronto-parietal). In the present study only one such case was included, however by excluding these, in future research unnecessary confounding of the data could be avoided.

These data suggest that the KCT-D may have a component which is amenable to left hemisphere processing, as evidenced by the relatively poor performance by patients with LA lesions on KCT-D. The fundamental nature of this component may be either verbal or sequential. Future research could 'tease out' which of these components is involved. One strategy for examining the verbal component may involve filling the delay with a counting task. Although De Renzi et al. (1977) found that filling the delay with a distractor task did not change overall performance on the Corsi Block task it may have an effect on performance of the KCT-D. In addition, it may be possible to determine whether the LA group was relatively impaired on KCT-D because of impaired application of verbal strategies by designing a test in which they are provided with the verbal strategy. For example, the blocks could have numbers placed on them and/or the examiner could verbalize the digits as they tap the cubes. If the LA group is unable to use the verbal strategy provided then it is more likely that their deficit on the KCT-D was due to the misapplication of, or inability to use, verbal strategies. If, on the other hand, their performance does improve some other explanation must be found. Another suggestion involves developing a second set of sequences. In the present study the same sequence of

spans was used for both KCT-I and KCT-D; whereas, a different set of digits was used in each of the digit span tasks. It is thus possible that there was more proactive interference with the digit span tests than with the KCT-R tasks and, similarly, there may have been a stronger practice effect with the cube as opposed to the digit span tests. By using two different sets of sequences for KCT-I and KCT-D the possibility of any practice effects would be reduced and, in addition, any proactive interference would affect both the digit and cube tests equally. The actual response of the patient could be recorded and then the pattern of errors could be examined. One final suggestion for future research involves restructuring the KCT-D task such that the patient would be asked to tap the cubes in the reverse order tapped by the examiner. This would make the task more cognitively complex as well as more difficult. It also may eliminate the poor performance in patients with LA lesions by adding a stronger visuospatial component. In addition, this modification would make the KCT-R even more analagous and hence more comparable to digit span tests. Having more analagous tests would allow for more accurate assessment of spatial and verbal immediate memory (attention span) deficits in patients with localized cerebral lesions. In addition, by comparing and contrasting patients abilities on multiple tasks we may begin to understand the complex mechanisms which underly higher cognitive functioning.

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